

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) RELUCTANCE MOTORS

(71) We, NATIONAL RESEARCH DEVELOPMENT CORPORATION, a British Corporation established by statute of Kingsgate House, 66—74 Victoria Street, London, S.W.1., do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to reluctance motors. Such motors comprise a stator structure having a single-phase or multi-phase winding arranged to provide a rotating or pulsating multi-pole magnetic field and a rotor structure provided with a squirrel cage winding similar to the winding of an induction motor and an anisotropic distribution of magnetic material arranged to match the stator multipolar magnetic field so that in operation the rotor runs up to near synchronous speed in a manner similar to an induction motor and thereafter locks on to the stator magnetic field and rotates in synchronism therewith.

It is an object of the present invention to provide a rotor for reluctance motor of novel construction and a further object is to provide a rotor capable of operating with a pole changing stator winding at any of its pole members.

According to the present invention a reluctance motor comprises a stator member wound to provide a magnetic field having p pole-pairs and a rotor member of magnetic material having a squirrel-cage winding and not more than p flux barriers, each flux barrier being symmetrical about a common diametral line and the flux barriers lying symmetrically distributed about a diametral line perpendicular thereto, the flux barriers terminating at positions which are within the rotor member.

In carrying out the invention the positions of the ends of each flux barrier relative to the said single diametral line is preferably such as to subtend an angle of $\pm \alpha_n$ radians where

$$\alpha_n = \frac{\pi}{2p} (2n - 1) \text{ and } n \text{ takes all whole numbers from } 1 \text{ to } p \text{ inclusive.}$$

[Price 5s. 0d. (25p)]

This provides that the circumferential distances between the ends of adjacent barriers are equal.

According to a further feature of the invention the stator member is wound to provide a magnetic field having either p_1 or p_2 pole pairs by means of pole changing techniques, for example the technique which has become known as pole-amplitude modulation. Where p_2 is not an integral multiple of p_1 the rotor member is provided with $p_1 + p_2$ flux barriers and where p_2 is an integral multiple of p_1 then only p_2 flux barriers are provided. With such an arrangement the rotor is capable of rotating synchronously with a magnetic field having either p_1 pole pairs or p_2 pole pairs.

The invention is further applicable to three-speed or four-speed combinations by the provision of a rotor having a number of flux barriers equal to the sum of the numbers of pole pairs for which the stator is wound. However where any of the pole pairs is an integral multiple of another the smaller pole pair may be ignored. For example, with a stator arranged to provide 2, 3 or 4 pole pairs it is sufficient to provide a rotor having 7 (i.e. 3+4) flux barriers.

In order that the invention may be more fully understood reference will now be made to the accompanying drawings in which:—

Figures 1 to 6 illustrate in section rotors having pole pairs of from 1 to 6, respectively,

Figure 7 illustrates a rotor suitable for a pole-changing pole-amplitude modulated motor having 6/8 poles and

Figure 8 illustrates a modification of the machine illustrated in Figure 7.

Referring now to Figure 1 there is shown therein a rotor 1 of a reluctance motor having a squirrel cage winding comprised of bars 2 positioned around the periphery of the rotor. The rotor is designed to be mounted within a stator (not shown) having a conventional distributed winding arranged to provide a two-pole rotating magnetic field, i.e. the number of pole pairs p is unity. The rotor is provided with one flux barrier 3 which lies on a dia-

metral line YY'. Barrier 3 is thus both symmetrical about the diametral line XX' perpendicular to YY' and lies symmetrically distributed about the diametral line YY'.

5 Figure 2 illustrates a rotor designed to be used with a stator having a four-pole rotating magnetic field i.e. with two pole pairs. The rotor illustrated in Figure 2 has two flux barriers 4 and 5 each symmetrical about the line XX' and the two barriers are symmetrically distributed about the line YY'. Barriers 4 and 5 are curved to follow the lines of the preferred direction of flux through the rotor although this is not essential. The angles between the ends of the flux barriers 4 and 5

15 and the diametral line XX' are $\frac{\pi}{4}$ radians

and $\frac{3\pi}{4}$ radians as required by the above-mentioned formula.

Figure 3 illustrates a rotor for use with a six-pole stator field i.e. $p=3$ and three flux barriers 6, 7 and 8 are provided. Flux barrier 7 is in a similar position to the flux barrier 3 of Fig. 1 and flux barriers 6 and 8 are curved and their ends subtend an angle of $\frac{\pi}{6}$ and $\frac{5\pi}{6}$ relative to the line XX' in accordance with the formula.

Figure 4 illustrates a rotor for use with an eight-pole stator field i.e. $p=4$ and four flux barriers 9, 10, 11 and 12 are provided. There is no single barrier lying on a diametral line and all four barriers are curved the angles subtended by the ends of the barriers 9 and

12 to the line XX' are $\frac{\pi}{8}$ and $\frac{7\pi}{8}$ radians

and the angles subtended by the remaining

35 barriers 10 and 11 are $\frac{3\pi}{8}$ and $\frac{5\pi}{8}$ radians.

Figure 5 illustrates a rotor for use with a 10-pole stator field i.e. $p=5$ and five flux barriers are provided. One of these barriers, namely barrier 15, follows the diametral line YY' and the other four barriers are positioned symmetrically on either side thereof. In this case the angles α_1 and α_3 (representing the angles subtended by the shortest flux barriers)

are now $\frac{\pi}{10}$ and $\frac{9\pi}{10}$ and α_2 and α_4 (representing the angles subtended by the intermediate flux barriers) are $\frac{3\pi}{10}$ and $\frac{7\pi}{10}$ radians.

Figure 6 illustrates a rotor suitable for use with a 12-pole stator field i.e. $p=6$ and six barriers are provided. There is no central barrier and the ends of the barriers subtend

angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$, and α_6 respectively, of values $\frac{\pi}{12}, \frac{\pi}{4}, \frac{\pi}{12}, \frac{5\pi}{12}, \frac{7\pi}{12},$ and $\frac{3\pi}{4}$

$\frac{11\pi}{12}$.

It will be appreciated that in all of the above described arrangements the reluctance of the rotor when in the direct axis position will be much less than when the motor is in the quadrature axis position at 90 electrical degrees thereto. In each figure the polarities of the rotor in the quadrature axis position are marked.

The arrangement described with reference to Figures 1 to 6 can be adapted for pole changing motors. Thus where a stator is designed to provide a pole number of either p_1 or p_2 and neither pole number is an integral multiple of the other than the rotor can be provided with $p_1 + p_2$ flux barriers. Thus for example for a machine designed to have either 6 or 8 poles, in which case $p_1=3$ and $p_2=4$, seven flux barriers are provided on the rotor these corresponding to the superposition of the flux barriers illustrated in Figure 3 with the flux barriers illustrated in Figure 4. Such an arrangement is illustrated in Figure 7.

If the higher number of pole pairs p_2 is an integral multiple of the lower number of pole pairs p_1 , then the number of flux barriers needs to be p_2 only, since the flux barriers provided for the larger pole-number also limit the quadrature axis flux for the smaller pole number.

The invention is also applicable to three-speed pole combinations either by the provision of a number of flux barriers equal to the total sum of the pole numbers or else, in certain cases where one pole number is an integral multiple of another it is only necessary to provide flux barriers equal to the sum of two of the number of pole-pairs. For example the arrangement illustrated in Figure 7 for a 6/8-pole combination may also be used for a 4/6/8-pole combination since the largest of the pole numbers is an integral multiple of the smallest of the pole numbers.

It is also possible to apply the principle to a four-speed pole combination in which case the number of flux barriers can generally be kept down to a reasonable value, due to the fact that one or more of the larger pole numbers may be integral multiples of the smaller pole numbers. Thus for example the arrangement of Figure 7 can be used for any of the following pole combinations namely 6/8, 4/6, 2/6, 2/4/6, 4/6/8, and 2/4/6/8.

It will be seen from Figures 1 to 6 that the diametral line XX' always coincides with two quadrature axes. Thus in the case of the Figure 7 arrangement designed for both a 6-pole and an 8-pole combination quadrature

axes for both combinations coincide along the line XX'. Accordingly the two outer pairs of flux barriers 24, 25 and 29, 30 may be replaced by axial grooves as in a conventional reluctance type rotor. Such an arrangement is illustrated in Figure 8 where axial grooves 31 and 32 are shown in place of the outer pairs of flux barriers in Figure 7.

It will be appreciated that in the case of a single speed machine any of the outermost flux barriers may be similarly replaced by axial grooves. In general, appropriate combinations of flux barriers and axial grooves, the disposition of which follow the principles given herein, can be used.

In all of the above figures the flux barriers terminate at positions which are within the rotor member.

WHAT WE CLAIM IS:—

1. A reluctance motor comprising a stator member wound to provide a magnetic field having p pole-pairs and a rotor member of magnetic material having a squirrel-cage winding and not more than p flux barriers, each flux barrier being symmetrical about a common diametral line and the flux barriers lying symmetrically distributed about a diametral line perpendicular thereto, the flux barriers terminating at positions which are within the rotor member.

2. The reluctance motor as claimed in Claim 1 in which at least some of the flux barriers are curved and their ends lie in planes extending radially of the rotor.

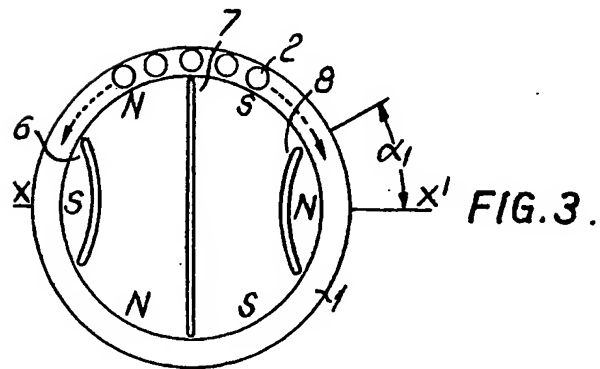
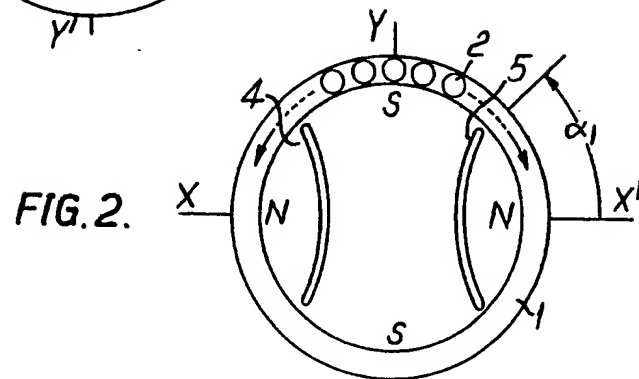
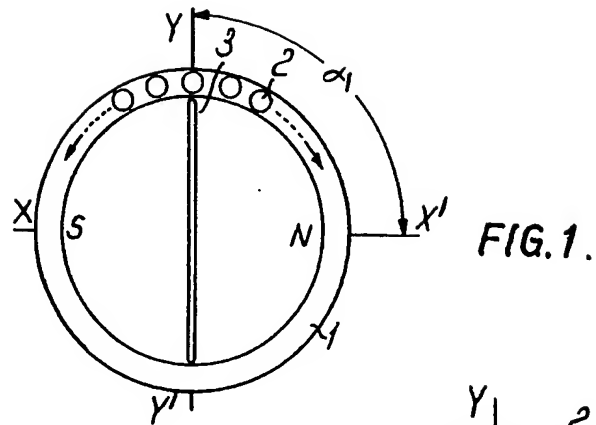
3. The reluctance motor as claimed in Claim 1 or Claim 2 in which the distances around the circumference of the rotor between the ends of adjacent barriers are equal.

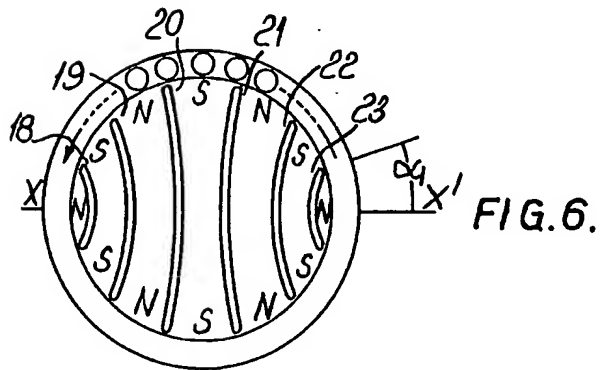
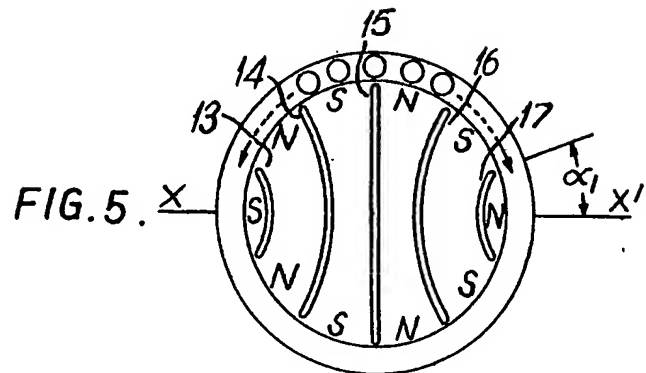
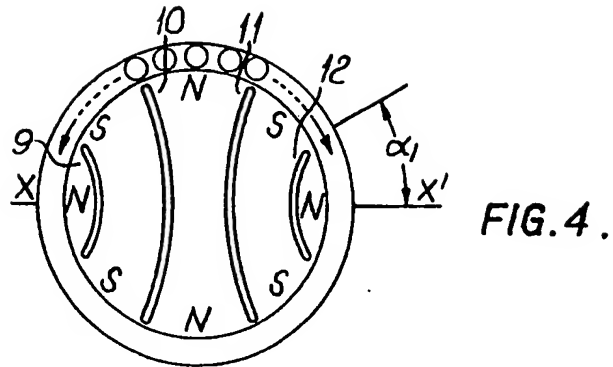
4. The reluctance motor as claimed in any one of the preceding claims in which the number of flux barriers is less than p by an even number and two circumferential channels are provided on the rotor positioned at opposite ends of the said single diametral line.

5. The reluctance motor as claimed in any one of the preceding claims in which the stator member is wound to provide magnetic fields having a plurality of different alternative pole numbers and the number of flux barriers is not more than the sum of the different alternative pole pairs that are provided, ignoring any pole pair which is an integral multiple of another pole pair.

6. A reluctance motor substantially as described with reference to any one of the figures of the accompanying drawings.

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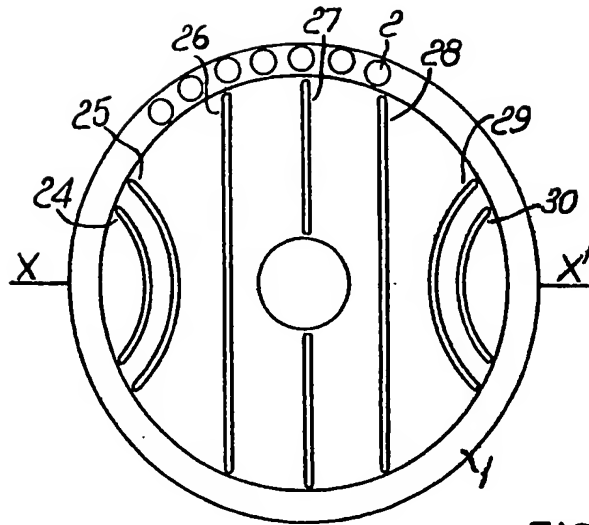


FIG. 7.

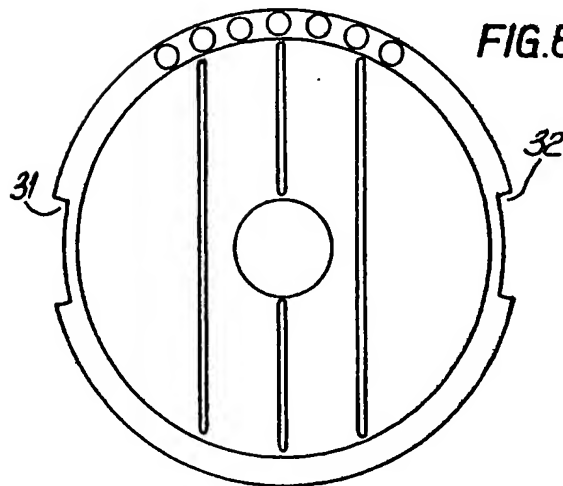


FIG. 8.